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POWERPLANT GROUP CHAIRMAN'S FACTUAL REPORT

by

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NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF AVIATION SAFETY
WASHINGTON, D.C.

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POWERPLANTS GROUP CHAIRMAN'S FACTUAL REPORT

DCA94MA076

A. ACCIDENT

Location:	Aliquippa, Pennsylvania
Date:	September 8, 1994
Time:	1904 Eastern Daylight Time
Airplane:	USAir, Boeing 737-300, Flight 427, N513AU

B. POWERPLANT GROUP

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C. SUMMARY

On September 8, 1994 at 1904 Eastern Daylight time, USAir flight 427, a Boeing 737-300, N513AU, crashed while maneuvering to land at Pittsburgh International Airport, Pittsburgh Pennsylvania. The airplane was being operated on an instrument flight rules (IFR) flight plan under the provisions of Title 14, Code of Federal Regulation (CFR), Part 121, on a regularly scheduled flight from Chicago-O'Hare International Airport, Chicago, Illinois, to Pittsburgh. The airplane was destroyed by impact forces and fire near Aliquippa, Pennsylvania. All 132 persons on board the airplane were fatally injured.

The airplane impacted the terrain in a nose-low, upright attitude in a southwesterly direction. The accident site was on gradually sloping wooded terrain, divided by a dirt road. The dirt road headed in an east-west direction, with steep up-sloping banks along the north and south sides. The nose of the airplane impacted the south bank. The left wing extended into the woods and the left engine impacted the top of the south bank, just inside the tree line. The right wing extended diagonally across the road and the right engine impacted the slope of the south bank.

Review of the DFDR data and the wreckage revealed evidence that both engines were operating normally and the auxiliary power unit (APU) was not operating, up to ground impact. The evidence revealed no failures or preexisting conditions that would have prevented normal engine or APU operation. The damage to the engines, nacelles and pylons was consistent with impact in a nose-low attitude, at high-speed, with the engine low and high pressure rotors rotating. The burned hardware, and soot patterns on both engines and the auxiliary power unit were consistent with postcrash fire. All the separated engine-to-pylon and pylon-to-wing attachment hardware were fractured in overload. Physical evidence indicated that the thrust reversers were in the stowed position at impact.

D. DETAILS OF THE INVESTIGATION

1. ENGINE HISTORY AND DESCRIPTION

The airplane was powered by two CFM International CFM56-3B-2 engines operated at the 3-B1 thrust rating.

	Engine No. 1	Engine No. 2
Serial No.:	725150	720830
Total Hours:	13,880	16,810
Total Cycles:	9,474	9,918
Hours Since Installation:	3,462*	3,789**
Cycles Since Installation:	2,160	2,340

* No. 1 engine installed August 1993.
** No. 2 engine installed July 1993.

The engines were subjected to a normal performance restoration workscope at Aviall, Dallas, Texas, before installation. N513AU was initially configured for long range operation with the engines operating at the 3B-2 (22,100 pounds) thrust rating. The airplane was subsequently modified to the “standard range” configuration in January 1994, with the engines operated at the 3-B1 (20,100 pounds) thrust rating.

The CFM International CFM56 engines are dual rotor, axial flow, high-bypass turbofan engines and may be operated at a 3-B1 thrust rating of 20,100 pounds or a 3B-2 thrust rating of 22,100 pounds at 86° F, sea level conditions, depending on the airplane installation. The low pressure compressor, or booster, has three stages with a single-stage fan and is driven by a four-stage turbine. The high pressure compressor has nine stages and is driven by a single-stage turbine. The high pressure rotor drives the accessory gearbox by way of a transfer gearbox and a radial drive shaft. The burner section uses an annular combustor with 20 fuel nozzles and two igniters.

2. PYLON DESCRIPTION

The pylon is a streamlined strut that positions the engine below and forward of the airplane wing and transfers all the thrust, gravity and side loads from the engine to the wing. Additionally, the pylon provides a path for electrical wiring, fluid lines and bleed air ducts to the airplane. The pylon is a semimonocoque structure, fabricated from sheet metal skin, longitudinal spars, stiffeners, ribs and bulkheads. The pylon is attached to the wing by fuse pins at four attachment points; the upper wing fitting, the inboard and outboard mid-spar fittings, and the diagonal brace wing fitting. In addition, two side braces, links and fittings connect the pylon and wing.

The engine is attached to the pylon at four attachment points; two forward engine mounts, thrust link fitting and the aft engine mount. The forward engine mount attaches the fan case to the front pylon bulkhead with two cone bolts and two clevis fittings. The thrust link fitting attaches the engine fan case to the pylon with thrust mounts, thrust links, evener bar, and fail safe fitting. The rear engine mount attaches the turbine case to the aft pylon bulkhead with a cone bolt, a hanger fitting and two links.

3. NACELLE DESCRIPTION

The nacelle houses the engine, components, and accessories, and thrust reverser system. Each nacelle consists of an inlet duct, two fan cowls, exhaust nozzle, exhaust centerbody, two thrust reverser “C” ducts with integral translating cowls and core cowls. The “C” ducts are hinged at the top along the base of the pylon and are latched along the bottom. The “C” ducts support the engine in the event of an engine mount separation.

4. THRUST REVERSER DESCRIPTION

The thrust reverser is a hydro-mechanical system that provides the pilot with a means to decelerate the airplane on the runway by altering the direction of the fan air flow. The main components of the thrust reversing system include a cockpit lever, hydraulic control valve module, linear hydraulic actuators, translating sleeves, blocker doors, and cascades.

During forward thrust operation, the translating sleeves are fully retracted (forwardmost position) such that the blocker doors are recessed into the outer wall. During reverse thrust operation the translating sleeves translate aft forming an annular opening between the fan and translating sleeves, and pulls the blocker doors from their recess. The blocker doors form a wall, normal to the fan air flow which direct the fan air flow radially outward through the annulus. Cascades are the turning vanes that line the annulus, and direct the airflow into the desired external flow pattern or efflux.

Actuation of the thrust reverse levers by the pilot deploys the reversers and sets reverse thrust power. The thrust control interlock mechanism, mounted inside the wing leading edge, limits command of increased thrust if either translating sleeve is not in its commanded position. The same mechanism will drive the thrust command to a low thrust level if either sleeve translates out of its commanded position while operating at high thrust.

5. ON-SITE INVESTIGATION

The go-team arrived at the accident site on the morning of September 9, 1994. The Powerplant Group organized and proceeded with the documentation of the pylons, nacelles, thrust reversers, engines and the auxiliary power unit (APU).

Both the No. 1 and No. 2 engines were broken into several sections and separated from their respective pylons. The pylons, nacelles, and reverser components from both engines were fragmented into pieces and scattered around the impact craters of their respective engine and scattered about the accident site to the extent that they could not be readily associated with a particular engine before matching serial numbers with the maintenance records. None of the pylon, nacelle, engine, or reverser components were found remote from the accident site.

5.1 PYLONS/ENGINE MOUNTS

All of the major engine-to-pylon and pylon-to-wing fittings and attachment hardware for both pylons was recovered and tabulated below:

	Engine No 1	Engine No. 2
WING FITTINGS		
Upper wing fitting:	Intact, separated from wing, (wing forward)	Intact, separated from wing, (wing forward)
Fuse pin:	Intact	Intact
Inboard midspar fitting:	Intact (on wing)	Intact, separated from wing (wing forward)
Fuse pin:	Sheared	Intact
Outboard midspar fitting:	Intact, separated from wing (wing forward)	Intact, separated from wing (wing forward)
Fuse pin:	Sheared (engine aft)	Intact
Diagonal brace wing fitting:	Fractured (wing forward)	Fractured (wing forward)
Fuse pin:	Sheared (brace aft)	Sheared (brace aft)
Side brace wing fitting:	Fractured	Fractured
UPPER PYLON		
Upper link:	Intact	Intact
Side braces:	3/4 Intact	Intact (bent)

	Engine No 1	Engine No. 2
UPPER PYLON (CON'T)		
Diagonal brace:	Fractured (compression)	Intact
Upper link pylon fitting:	Intact (fractured mid beam)	Intact (fractured mid beam)
Pin:	Intact	Intact
Outboard midspar pylon fitting:	Upper tang fractured	Upper tang fractured
Inboard midspar pylon fitting:	Both tangs fractured	Upper tang fractured
Side brace pylon fittings:	Intact	Intact
LOWER PYLON		
Front pylon bulkhead:	Not located	Not located
Fail safe fitting:	4 of 4 tangs fractured	1 of 4 tangs fractured
Thrust fitting:	Fractured post	Intact
Evener bar:	Intact but twisted	End fractured
Left side thrust link:	1 of 4 clevis ends fractured	2 of 4 clevis ends fractured
Right side thrust link:	2 pieces & 4 of 4 clevis ends fractured	2 pieces & 4 of 4 clevis ends fractured
R-H Engine Fan case thrust mounts:	Intact	Intact
L-H Engine Fan case thrust mounts:	Intact	Fractured
Rear engine mount pylon: cone bolt:	Intact but bent (engine aft)	Intact but bent (engine aft)
L-H Rear engine mount hanger fitting:	2 of 4 clevis ends fractured (inboard aft)	
R-H Rear engine mount hanger fitting:	1 of 4 clevis ends fractured (inboard aft)	
Rear mount links:	Both fractured	Both fractured
R-H Turbine case lugs:	Both Intact (R-H case wall pullout)	
L-H Turbine case lugs:	Both Intact	
Diagonal brace pylon fitting:	Intact, separated from pylon bulkhead	Intact
Pin:	Intact	Intact

5.2 NACELLES

5.2.1 Nacelle - Engine No. 1

Both halves of the thrust reverser latch-beam assembly were recovered with latches damaged, and forward latch connected. Portions of both translating sleeves remained within their respective track, and were positioned approximately 1 inch forward of the stowed position. Portions of the inboard and outboard hinge beam assemblies were recovered, both with portions of the translating sleeve within their respective track.

The outboard thrust reverser torque box/fire wall (TB/FW) structure was fragmented. The “C” duct data plate was not found. The upper or locking head actuator and cylinder were identified by process of elimination because the remaining three locking actuators were uniquely identified by the TB/FW structure. The center actuator was determined by the process of elimination, to be one of two non-locking actuators in the stowed position. The lower actuator was identified by TB/FW structure.

The inboard thrust reverser TB/FW structure was fragmented. The section of TB/FW structure, with C duct S/N 00324 data plate attached, retained the center actuator head. The upper or locking actuator was identified by matching the fracture surface of the doubler around the actuator. The center actuator cylinder was identified by matched TB/FW fracture surfaces. The lower actuator was identified by a process of elimination, and was determined to be one of two stowed, non-locking actuators.

Fragments of the cascades, blocker doors, cascade support rings, core cowls, fan cowls, hinges, latches, and part of the inlet lip and bulkhead and a fragment of the inlet wall containing the T2 sensor was recovered. Part of the pylon containing the push-pull cables for the thrust control, fuel shut-off control, and reverser feed back cables were recovered with all cables stretched, broken and fittings missing.

The head end of both locking actuators were separated from the hydraulic actuator cylinders and piston rods exposing the aft face of the hydraulic actuator pistons. Both hydraulic actuator pistons were visible inside the head end of the actuators, in the stowed position. The two locking heads were boxed for teardown inspection at Dowty Aerospace, Duarte, California.

5.2.2 Nacelle - Engine No. 2

Both halves of the thrust reverser latch-beam assembly were recovered with the latches connected but damaged. The inboard latch-beam slider track was undamaged. The lower portion of the inboard translating sleeve was found separated and next to the latch beam assembly. The lower portion of the outboard translating sleeve remained in the track, and positioned approximately 2 inches aft of the stowed position. Portions of the inboard and outboard hinge beam assemblies were recovered with fragments of the translating sleeve within their respective track. Parallel gouges, in line to the direction of flight, were found on the lower track faring, lower inboard translating sleeve fragment and slider and were consistent with sliding contact with the ground.

The inboard thrust reverser TB/FW structure was fragmented with three sections, each retaining an actuator. The sections with the actuators were identified by matching fracture surfaces. The upper or locking head actuator and cylinder were both separated and identified by matching their respective fracture surfaces. The lower section had the “C” Duct S/N 00323 data plate attached, with the actuator loose in the pass-through opening.

The outboard TB/FW structure was fragmented into three major sections with each retaining an actuator. The upper and lower sections of TB/FW were identified by matching the fracture lines with in the center TB/FW section. The lower section had “C” Duct S/N 00325 data plate attached.

Fragments of the cascades, blocker doors, cascade support rings, core cowls, fan cowls, hinges, latches, and approximately 60% of the inlet lip and bulkhead were recovered.

The head end of the inboard locking actuator was separated from the hydraulic actuator cylinder and piston rod exposing the aft face of the hydraulic actuator piston head. The outboard locking actuator was only partially separated from the hydraulic actuator cylinder; however, both hydraulic actuator pistons were visible inside the head end of the actuators, in the stowed position, The two locking heads were boxed for teardown inspection at Dowty Aerospace, Duarte, California.

The following table documents the thrust reverser actuators at the accident site:

Thrust Reverser Hydraulic Actuator Summary

	Engine No. 1		Engine No. 2	
Actuator	**Outboard**	**Inboard**	**Inboard**	**Outboard**
Upper (Locking)	**Stowed, (Cylinder, rod, lead screw, separated at base of piston, separated rod end)**	**Stowed, (Cylinder, rod, separated at base, of piston separated rod end)**	**Extended, (Cylinder, lead screw separated at base of piston, rod end & spring pack intact)**	**Extended, (Cylinder & rod separated at base of piston, rod end intact)**

	Engine No. 1		Engine No. 2	
Actuator	Outboard	Inboard	Inboard	Outboard
Middle (Non-Locking)	Stowed, (Cylinder Intact, separated rod end)	Extended, (Cylinder, lead screw separated aft of gimbal, separated rod end)	Stowed, (Intact, separated rod end)	Stowed, (Cylinder & rod end intact)
cower :Non-Locking)	Stowed, (Cylinder, with rod end, spring pack, cascade ring intact)	Stowed, (Intact, separated rod end)	Stowed, (Intact, separated rod end)	Stowed (Cylinder & rod end with sleeve fitting

Details of the four locking head thrust reverser actuators conducted at Dowty Aerospace are contained in Addendum C of this report.

5.3 ENGINES

Engine and main engine control (MEC) serial numbers were recovered and verified to be on their respective wing or engine in accordance with the maintenance record.

5.3.1 Engine No. 1

The No. 1 engine, although separated into two major sections, was fragmented into pieces, burned, and located under the left wing wreckage. The thrust axis of fan case, booster, and the forward half of the high pressure compressor (HPC) was approximately vertical to the earth, whereas the low and high pressure turbines (LPT and HPT) were resting at approximately a 45° angle, front-end low. The aft portion of the HPC and the combustion case were fragmented to the extent that disks were loose in the engine impact crater. The fan case, booster and HPC cases were crushed together and deformed into an oval. The main engine control (MEC), serial number WYG53647, separated into two pieces but remained intact with the main fuel pump. The right hand VSV actuator stroke was measured at 2.955 inches. The left hand VSV actuator remained attached to the lower half case but was inaccessible. None of the nacelle structure remained attached to the engine.

5.3.1.1 Fan, LPC and HPC

The fan case/fan frame assembly and rotor was integral to the booster and the forward end of the HPC; however, the fan case separated into two sections when lifted during inspection. There were no penetrations in the fan case in the plane of rotation of the fan. A 3-inch diameter hole was noted aft of the rotor plane, in front of the OGV's at the 7:30 o'clock position. The edge of the hole was flared to the exterior. The booster module was crushed to approximately 9-10 inches in axial length.

All the fan blades were bent opposite the direction of rotation and fragmented at various lengths above the dovetail plafforms with both sharp and shallow bending on the leading and trailing edges. Five of the fan blades, retained within the fan disk, included the midspan shrouds. The fan disk was intact and all fan blade dovetails were in their installed position. All the midspan shrouds and portions of all 38 blades were recovered. A black light inspection of the fan blades revealed indications of random traces of organic matter similar in appearance to blood. The organic matter indications could not be associated with any specific leading edge area damage nor were of sufficient quantity to consider further analysis.

The forward HPC case was of the titanium configuration. The upper half of the forward HPC case, including stage 1 vanes through the stage 4 rotor plane, separated from the engine aft of stage 1 rotor plane. The lower half forward HPC case, with the IGVs through stage 2 vanes, remained attached at the forward engine half and was split 30° circumferentially from the 3 o'clock split line. The lower extension case half was crushed against the aft compressor and combustion cases and approximately 170° of aft flange of the upper extension case was recovered. There were no case penetrations in the rotor planes of stages 1,2,3, and 4. Stage 2 rotor path liners were in their installed position except one at the 3-4 o'clock position, which was recovered from within the HPC.

The forward half of the HPC rotor retained the HPC forward shaft, stage 1-2 spool, and stage 3 disk. The stage 4,5, and 6 compressor disks were separated from the HPC rotor and recovered from the engine impact crater. The stage 7 and 8 HPC disks were intact and with the stage 9 HPC disk between the two major engine halves. The aft flange of the 4-9 spool, forward HPT shaft and compressor discharge pressure (CDP) airseal remained intact. All HPC blades were in their installed position and separated at the blade platforms.

The inspection of the individual HPC disks revealed the following:

STAGE	COMMENTS
4	Disk and rim intact.
2	Disk intact. Rim separated through 360° of the circumference. Recovered 10 pieces of rim section accounting for 50 of 53 blades slots.
3	Disk and rim intact. Disk web area separated approximately 3 inches from the disk flange.
4	Disk and rim intact.

STAGE	COMMENTS
5	Disk intact with rim separated approximately 190° of arc. 4 rim pieces recovered missing a 3-inch segment of circumference.
6	Disk and rim intact.
7-8	Disks and rims intact.
9	Disk intact. Rim torn from disk web for approximately 300° of arc but remained attached to the inner bore.

5.3.1.2 Combustor, HPT and LPT

The combustion case, high pressure turbine assembly remained attached to the LPT module. The LPT shaft separated in bending with evidence of torsional loading, in the plane of rotation of the stage 1 HPC. The case was partially collapsed and split between approximately 2-9 o'clock exposing the combustor, and HPT nozzle assembly. The HPT forward shaft separated from the disk approximately 7 inches aft of the rotating CDP seal. Circumferential rub marks with blue discoloration were noted about the outer diameter of the HPT shaft. The HPT blades sustained trailing edge and tip damage as viewed through an opening in the LPT case.

The LPT case was split circumferentially forward of the turbine frame forward flange approximately 130° of arc centered at 12 o'clock, exposing the stage 4 LPT disk/blade assembly. The width of the opening was approximately 18 inches. Stages 3 and 4 disk blade assemblies were deformed radially inward and forward. Numerous blades were also visible through the case opening. The turbine frame, exhaust nozzle and aft center body were integral to the LPT module. The exhaust nozzle was crushed radially inward and forward. Inspection of the visible stage 4 LPT blades revealed blades to be in their installed disk dovetails with radial deformation.

5.3.2 Engine No. 2

The No. 2 engine, although separated into three sections, was fragmented into pieces burned, and located in the vicinity of the right wing impact point. The fan, LPC and forward half of the HPC were buried in the ground with the thrust axis approximately vertical to the earth. The fan case, and several fan blades were adjacent to the horizontal stabilizer, and the turbine module was separated by approximately 20 feet and resting at about a 45° angle, front-end low. The HPC was fragmented with disks and cases scattered around the accident site. The MEC and throttle box, serial number WYG64694, remained intact with the main fuel pump. None of the nacelle structure remained attached to the engine. The right hand VSV actuator was attached to the separated upper half HPC case with the stroke measured at 2.932 inches. The left hand VSV actuator remained attached to the lower half case with the stroke measured at 2.884 inches.

5.3.2.1 Fan, LPC and HPC

The fan rotor was integral to the booster and forward half of the HPC; however, the fan case was separated and in two pieces. Two penetrations were found in the fan case in the plane of rotation of the fan, at approximately the 12 and 1 o'clock positions with the edge of the holes flared inward. The booster rotor system was crushed in the axial direction to a length of approximately 7 inches. A section of the stage 1 and 2 booster blades were visible over a 90° arc through a split in the inner fan shroud. The stage one blades were sheared at the platforms. The stage 2 blades were crushed radially inward.

The HPC stages 1, 2 and 3 were contained within the fan module. The remaining disks were scattered between the front half of the engine and the rear half of the HPC. The stage 1,2, and 3 disks were removed from the aft end of the fan module.

All the fan blades were bent opposite the direction of rotation and fragmented at various lengths at or above the dovetail platforms with both sharp and shallow bending on the leading and trailing edges. The fan disk was intact and all fan blade dovetails were in their installed position. Thirty-two fan blade fragments, with midspan shrouds, and portions of all 38 blades were recovered of which 25 blades were identified by position. A black light inspection of the fan blades revealed indications of random traces of organic matter similar in appearance to blood. The organic matter indications could not be associated with any specific leading edge area damage nor were of sufficient quantity to consider further analysis.

The HPC forward case assembly was of the steel case configuration. A portion of the upper half of the forward HPC case, from the IGVs through the plane of rotation of the 4th stage rotor, separated from the front half of the engine with no case penetrations noted. The lower half of the forward HPC case, including the combustion case forward support, also was separated from the from the front half of the engine. Both halves of the HPC aft case separated from the forward HPC case but remained attached to each other. There were no penetrations in the planes of rotations of stages l-5 or stages 6-9.

The HPC rotor system was reconstructed with the following observations:

STAGE	COMMENTS
1	Disk and rim intact. One disk post separated from the disk. Four blades, found in their installed position, were sheared at the blade platform.
2	Disk and rim intact. Circumferential crack in the disk web over 155° arc.
3	Disk and rim intact. Cracked circumferentially in the disk web over 55° arc. 10 blades remained in their installed position and bent opposite the direction of rotor rotation.
4	Disk intact. The rim separated approximately 180° arc. The separated piece of disk web and 2 pieces of disk rim were recovered, accounting for all of the separated rim section.
5	Disk intact. Rim separated through 360° of arc, with 6 pieces of rim section recovered accounting for 270° of arc.
6	Disk intact with rim separated approximately 110° arc with one piece recovered accounting for approximately 35°
7	Disk and rim intact.
8-9	The disk pair remained as a unit with both disks and rims intact.

5.3.2.2 Combustor, HPT and LPT

The aft section of the LPT shaft remained with the combustor/LPT module. The LPT shaft separated in bending with evidence of torsional loading, in the plane of rotation of the stage 1 HPC. The combustion case was partially collapsed, separated from the HPC module aft of the forward combustor case flange, but integral to the LPT module. The HPT was not accessible. The LPT case was cracked circumferentially forward of the turbine frame flange from 7-3 o'clock, with the width of the opening was approximately 3/4 inch. The turbine frame was integral to the LPT module. The exhaust nozzle and aft center body were crushed together radially inward and forward. No case penetrations were noted.

Inspection of the stage 4 LPT rotor blades as viewed through an opening in the tailpipe, revealed all dovetails were in their installed position, and the blade tips were bent opposite the direction of rotation.

5.4 APU

The exterior of the APU was sooted, consistent with ground fire. The left, forward end, of the lower case was crushed rearward approximately 8-inches and upward approximately 3-inches. The APU case flange was ruptured, between the diffuser and combustion chamber, at the 6 o'clock position.

The 1st stage compressor blades were in operable condition. No circumferential rub marks were visible in the plane of rotation of the 1st stage blades. The compressor could not be manually rotated. The inlet support was fractured. The last stage of turbine blades and case were in operable condition.

5.5 ADDENDUM REPORTS

Addendum A documents the teardown inspection of the thrust reverser hydraulic control valves performed on October 17, 1994, at the Boeing Airplane Company, Seattle, Washington. Addendum B documents the teardown inspection of the lock heads for the thrust reverser hydraulic actuators performed on October 19, 1994, at Dowty Aerospace, Duarte, California.

Jerome D. Frechette

Jerome D. Frechette,
Powerplant Group Chairman

12/17/94